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AUTHOR Calingaert, Peter
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ABSTRACT

Systems of computer-assisted instruction (CAI) can be classified according to whether the author, student, or teacher controls the interaction between the student and the computer. Both author-controlled and student-controlled CAI have the advantages of individualized instruction, privacy for mistakes, and flexibility, but are tremendously expensive. Student-controlled CAI further allows a student to be much more active, but also makes supervision difficult. A teacher-controlled system used as another teaching tool before a whole class of students is much cheaper than the other types of CAI, and adds to the computer program an intelligent subsystem, the teacher, to filter input and modify the stream of presentation. Teacher-controlled CAI gives up the advantages of individual attention, privacy and flexibility, but the criterion of cost-effectiveness makes it an attractive possibility in the hands of a skillful teacher. (RH)

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Teacher Control in Computer Assisted Instruction

by

Peter Calingaert

University of North Carolina at Chapel Hill

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Abstract -- To many persons, computer-assisted instruction (CAI) connotes automated programmed instruction (PI). This exemplifies the author-controlled mode of CAI, in which PI, suitably generalized, is mediated by the computer. This mode is used effectively for tutorial instruction.

In another mode of CAI, the interaction between student and computer is under control of the student, perhaps within bounds set by an author. This student-controlled or discovery mode is most often seen in problem solving and in simulation, such as the ersatz laboratory.

A third mode, teacher-controlled CAI, is assuming increasing importance. Here the teacher intervenes in the student-computer interaction, generally with an entire class watching one terminal. In the hands of a skillful teacher, this mode offers most of the pedagogical advantages of the other two modes and costs far less.

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I. INTRODUCTION

Many ways of using the computer in instruction have been explored. Indeed, the expression computer-assisted instruction (CAI) has acquired almost as many meanings as users. Rather than attempt a precise definition, I shall merely indicate that I place a fairly broad construction upon the expression, encompassing by it most situations in which a computer system is interacting with one or more students who are attempting to derive knowledge or understanding from the system. I have found it enlightening to classify the many resulting forms of CAI by the agent controlling the interaction between student and computer.

At one extreme, that agent may be the author of instructional materials being mediated by the computer. At the opposite extreme is the student himself, deciding which programs (including his own) are to be invoked, in what sequence, and with what parameters. A middle ground is represented by the student's teacher as the agent of control. The boundaries separating these three modes of CAI are, of course, not always sharp. The essential differences which nevertheless distinguish them will be illustrated by several examples.

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II. AUTHOR CONTROL

Genesis

Author-controlled CAI is a direct descendant of programmed instruction (PI). The branching form of PI, due to Crowder [1], permits the individualization of subject matter. It is often encountered in the form of a scrambled PI text. In this form, a multiple-choice question is asked of the student, and his choice of answer dictates the next selection of material to be presented to him. The linear form of PI traces its mechanization to Pressey [2,3] and its defense to Skinner [4], who emphasizes the importance to educational effectiveness of having the student *construct* rather than *choose* the response to a question. To use a constructed response for branching requires automatic answer analysis. Not having this, Skinner prefers to keep constructed responses and gives up branching and therefore individualization. The difficulty of analyzing constructed responses by computer is responsible for the lesser impact which linear PI has had on CAI than has branching PI.

The obvious branching capability of the computer has made it a natural vehicle for the administration of branching PI. This may well be termed *computer-administered programmed instruction* (CAPI). In a computer, the branching can depend (in theory if rarely in practice) not only upon the choice of response, but

upon the student's last several responses [5], the time he takes to enter a response, his age, or a pseudorandom number. Moreover, the computer can record the interactions which occur and prepare analyses of student performance and of question performance. The erasability of the computer's storage media permits one to modify a set of instructional materials without reprinting an entire book or filmstrip. Frequent evolutionary improvement is therefore quite feasible.

Examples

The most glamorous form of CAPI is tutorial instruction in which the computer system presents new material to the student in a sequence and at a pace tailored to his individual needs. The multiple learning tracks available are selected by student responses to interspersed diagnostic questions.

It may be argued that the interaction in tutorial instruction is under control of the student, because the actions of the computer are dictated solely by the student's responses. The student does not know, however, what his responses signify to the computer. It is the course author who has determined for each possible student response what the corresponding computer action will be. The interaction is truly under author control.

The questions used to guide tutorial instruction may be effective in the absence of the tutorial material. If no

instruction is contemplated, this is computer-administered testing [6]. With the tutorial material retained, this is often called "drill and practice", a phrase which, as Dean points out, does not adequately distinguish the component parts [7]. If the questions test the student's command of facts, such as the multiplication table, the computer is administering drill [8]. If the questions test the student's application of facts and techniques, as in multiplying two-digit numbers, then the computer is administering practice [9]. If the questions are those on which a student has worked in advance, perhaps from a textbook, the computer is administering recitation, or problem review [10].

Evaluation

Author-controlled CAI has the following advantages.

1. It works; CAPI can be as effective as conventional classroom instruction [11].

2. It permits individualized instruction (a concept which Baker states itself needs further definition and study [12]).

3. It affords privacy for making mistakes. This is particularly important for adults.

4. It allows flexibility of scheduling, but does not demand flexibility unless the number of students in a class exceeds

the number of terminals available.

Many disadvantages, however, must be considered.

1. It is expensive to deliver instruction this way. For estimates ranging from very optimistic to very pessimistic, see [13-16].

2. It is very expensive to develop CAPI materials [13-16]. Estimates of the order of 100 hours of professional work per hour of lesson are still common. Effective the instruction may be, but it is rarely cost-effective.

3. If constructed responses are permitted, response analysis is difficult and determination of what action to take in return is equally difficult.

4. If constructed responses are not permitted, the instruction is severely constrained and teaching strategies are limited. Many CAPI materials are consequently monotonous.

III. STUDENT CONTROL

Forms

Student-controlled CAI gives the student a more active role in determining how the computer is to assist in instructing him.

Many forms of this mode of CAI can be envisaged.

A particularly exciting form is the automated library, which the student uses from his terminal. The problem of browsing has been mitigated, although not solved, by the development of hierarchical structures of information, such as Nelson's hypertexts [17]. However, the many problems of storing and retrieving information, whether in the form of documents or of facts, make this type of student-controlled CAI still more a wish than a reality.

Mention of the use of a computer to carry out a student's computation is perhaps obvious. It belongs in the catalog, nevertheless, because it is common and effective. An especially attractive form of this use is as an augmented desk calculator. The greatly enriched set of primitive functions available creates not merely a quantitative, but rather a qualitative difference between computer and conventional calculator. Moreover, the availability of program packages, such as for statistical analysis, further enhances the applicability of the computer.

Despite the foregoing, the notion of student-controlled CAI most often suggests experimentation with models. If the model is built by an author, the experimentation is called <u>simulation</u>, and the student is supposed to learn not by instruction but by discovery. Models have been written for such subjects as

mathematics, chemistry, and economics [18]. Often called ersatz laboratories (a term apparently due to Adams [19,20]), these models can be used when the true laboratory would be too expensive, too dangerous, or too time-consuming. Moreover, simplifying assumptions (e.g., absence of friction) and random variations (e.g., measurement errors) can be inserted or withheld to the degree desired.

If the model is built by the student, the experimentation is called problem solving. Teachers recognize that while teaching they also learn. A student, too, can learn while teaching, given a suitable pupil. Such a pupil is provided by the computer. The need for an algorithm forces the student to develop a logically consistent method of problem solution.

If models of the same phenomenon are prepared by both author and student, the computer can compare the models. By invoking the student's model with suitably chosen parameters, the computer system can perform diagnostic checking by looking for certain classes of errors in the student's model [21]. Alternatively, the student himself can compare the behavior of his model with that of the computer [22]. It is possible, of course, to limit the checking to simple comparison of outputs without diagnosis. A variety of the latter, common in arithmetic drill, is for the student and computer each to pose problems to the other, with the student deciding for each successive problem which partner

is to set the problem and which to solve it.

A highly developed form of student-controlled CAI would be a system to permit a student to rediscover the relations within our current conceptual system. Thompson has claimed that it is now within the state of the art to build such a CAI system within a single highly structured discipline, using techniques developed for question-answering systems [23].

Evaluation

Student-controlled CAI shares the advantages previously cited for author-controlled CAI. It works [24,25]; instruction is individualized; interaction is private; scheduling is flexible. Further advantages peculiar to the student-controlled mode are the following.

1. The student can receive a meaningful and pertinent answer to a response which was not specifically anticipated by the author.

2. The student's involvement in the interaction is active, not passive. This is likely to increase his motivation to learn [26].

3. Many types of materials, such as the ersatz laboratory, cannot reasonably be presented in author-controlled mode.

The usual cost disadvantages are present for student-controlled as for author-controlled CAI. There does exist evidence, however, that the ersatz laboratory can be less costly than the real laboratory [27]. A major disadvantage of student-controlled CAI is that supervision of the student becomes much more difficult. The author cannot keep the student from straying. If a teacher is present, part of the potential privacy is lost, and it is not clear to what extent the teacher should attempt to guide the student, nor even how best to guide him. We have had good experience, however, with a written laboratory instruction which the student could follow at his option if no better ideas struck him.

A further characteristic of this mode may be either an advantage or a disadvantage. It is very often the student who decides whether his understanding was right or wrong.

IV. TEACHER CONTROL

Philosophy

Teacher-controlled CAI represents an attempt to capture some of the advantages of the other two modes, without their disadvantages. The attempt rests on two complementary strategies. The first is to make use of the teacher, who, unlike the author, is present and, unlike the student, has the relevant

knowledge, experience, and judgment to manage the student's interaction with the computer. The second is to treat the computer system as a tool, much the way the teacher customarily treats chalkboard, textbook, and projector.

Mechanism

One tactic for achieving teacher control is to insert the teacher into an author-student system with means for monitoring and overriding the interactions [24]. This mechanism, commonly used in language laboratories, is not unlike the modes already discussed, with added complications. It is potentially more powerful, but surely still very costly.

A less expensive tactic is to place one computer terminal in the classroom, where it is operated by the teacher. The one interaction is made visible to the several students by means of opaque projector, closed-circuit television, or directly-connected video monitors. This second tactic is much simpler than the former, and deserves further scrutiny.

Examples

Two topics which I have taught in this mode are the iterative solution of systems of linear equations and the design of a serial binary adder. Although my personal interests have led me to select topics with considerable mathematical content, such is

no more a prerequisite for teacher-controlled than for author- or student-controlled CAI.

I introduce the first topic by displaying, using chalkboard or overhead projector, an arbitrary n by n system of equations written first in the customary manner, and then in a form in which the ith equation has been solved for the ith unknown. I then turn to a typewriter-based computer terminal whose output is visible to the class over closed-circuit television. Programs have been stored for checking a convergence criterion, and for solving a linear system by the Seidel method (of successive displacements) and by the Jacobi method (of simultaneous displacements). The latter two programs accept the initial approximation as a parameter and print out every jth iterate, where j can be reset at any time. By using these programs, written in a language which need not be familiar to the students, it is possible to explore the effect on convergence (which is truly seen as a process) of the choices of method, of starting value, and of order of the displacements. Although I start with a preplanned sequence of such choices, I usually modify them as I gauge my students' understanding and, indeed, in response to their questions and suggestions. The interaction which I supervise between the computer and the students can thus contain pedagogical elements found in the tutorial, desk calculator, simulation, and problem-solving forms of CAI. The lesson continues with a non-computer explanation of linear acceleration

followed by the use of a computer program based on the Seidel method, with acceleration used to calculate every kth iterate.

The binary adder presentation builds up computer program models of a half adder, a full adder, and a serial adder. Block diagrams of these devices are also shown. For this unit of instruction it is necessary that the students be able to program in the language used, because they are called upon to help rewrite an erroneous model of the serial adder.

My colleagues and I have used a graphic display terminal programmed to illustrate numerical methods of solving nonlinear equations and ordinary differential equations. This has been shown to be clearly more effective than spending an equal amount of time in conventional classroom instruction [28].

Evaluation

Teacher-controlled CAI, as here envisaged, foregoes three of the advantages of the other two modes. Most of the individual attention is lost, as well as privacy and flexibility of scheduling. Computer system failure now discommodes a whole class at once rather than an individually scheduled student. The teacher must therefore have a backup plan. This may be either an alternative presentation of the same material or a presentation of other material which is not enhanced by the

computer. Of course a backup plan is an asset for the other modes of CAI also.

Teacher-controlled CAI works, however, and I feel that the foregoing disadvantages, all minor save the loss of individualization, are outweighed by the following advantages.

1. Relying on his perception of the understanding and needs of his particular students, the teacher can effectively filter student inputs. In reply to a question, he can (a) transmit it unchanged to the computer, (b) rephrase and then transmit it, (c) request the student to rephrase it, (d) reject it as frivolous, (e) encourage the student to determine the answer without the computer, etc.

2. The teacher can interleave, with whatever frequency he judges best at the moment, prepared demonstrations and ad hoc responses to student questions.

3. The analysis of constructed responses and questions posed by the students is performed by a highly intelligent subsystem, the human teacher.

4. The teacher can use materials prepared by an author for the student-controlled mode and, with additional effort, materials for the author-controlled mode. He is free, of course, to modify such materials or to prepare his own.

5. Teacher-controlled CAI is much cheaper than the other two modes. A large reduction in development costs ensues because the teacher can be expected to handle exceptional situations which must otherwise be provided for in the computer program. Moreover, all terminal costs and many computer system costs are decreased, with respect to the terminal-per-student situation, by a factor of n in teaching a class of n students.

V. CONCLUSION

Chronologically, at least, CAI is no longer an infant, and it is time to pay more attention to cost-effectiveness and less to effectiveness alone. Neither the use of a computer system nor the development of computer programs and instructional materials is free of cost.

It may be argued that only a particularly skillful teacher can make effective use of such a complex and versatile tool as the computer. The ineffective manner in which some teachers use the chalkboard or textbook lend credence to this argument. Nevertheless, just as we attempt to teach prospective teachers not to erase what they have just written, nor to read long passages verbatim from the textbook, so can we attempt to teach the proper use of the computer as a tool. Any form of teaching is best in the hands of a skillful teacher.

Costs will have to be reduced yet further for CAI to be as attractive in primary and secondary as in post-secondary education. The extra time required can be well utilized in exposing future primary and secondary teachers to the uses of the computer in education.

It should be stressed that each teacher who wishes to enhance his teaching by use of a computer need not be compelled to develop his own materials. It is quite possible for authors to prepare CAI materials with teacher control in mind. There exist problems of standardization and distribution, to be sure, but these are no more severe than for the other modes of CAI.

The author-controlled, student-controlled, and teacher-controlled modes each use the capabilities of the computer system in a different manner. Teacher-controlled CAI offers most of the pedagogical advantages of the other two modes and costs far less. It therefore merits not only further investigation but also more widespread implementation.

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